

EFFECT OF LOW TEMPERATURE STORAGE ON SURVIVAL AND REPRODUCTION OF INDIANMEAL MOTH

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In California, the Indianmeal moth, *Plodia interpunctella*, is a major problem during processing and storage of dried fruit and nuts. Because current control practices rely on fumigation with methyl bromide, the impending loss of this fumigant has created the need for alternative treatment methods. One possible solution is to integrate short-term disinfestation methods with long-term protective techniques, such as low temperature storage. Because low temperature storage is an inefficient disinfestation method, the success of the integrated method depends on product entering storage as free of insects as possible. Assuming effective initial disinfestation, the most serious threat to the product would occur during transfer to low temperature storage, when the product is vulnerable to flying moths. For this reason, it is important to understand the effect of low temperature storage on both adults and eggs of the Indianmeal moth. Our study shows the effect of long-term exposure to 10°C on Indianmeal moth adult survival, reproduction and egg hatch.

Materials and Methods

Adult Mortality. From 139 to 221 adult moths of both sexes were placed at 10°C between 6 to 72 h after adult emergence. Adult mortality was determined weekly until all moths were dead. The test was repeated 3 times.

Adult Reproduction. At least 100 recently mated pairs and 100 unmated moths were placed at 10°C. Every 5 days, 10 mated pairs and 10 unmated females were removed and placed in oviposition cages. An untreated male was added to each cage containing an unmated female. The cages were placed on wheat bran diet and held under rearing conditions for 10 days, when hatched and unhatched eggs were counted. The test was continued for 30 days, and replicated 4 times.

Egg Mortality. Indianmeal moth eggs were placed at 10°C when 9 ± 8 , 30 ± 8 , and 54 ± 8 h old. For each age, about 300 eggs were removed after 4 days of exposure, and then every 2 days until 22 days. After removal from 10°C, the dishes were held at rearing conditions for 10 days, when hatched and unhatched eggs were counted. The test was replicated 4 times for the two youngest ages, and 3 times for the oldest.

Results

Adult Mortality. No significant difference was found between male and female mortality (Fig. 1). An average mortality of 50% was reached after 49 days of exposure, while 90% mortality was obtained after 70 days of exposure. Earlier work showed that the average lifespan of unmated moths kept at 27°C was 12.6 days (9-15) for females and 14.3 days (11-16) for males. Thus, 10°C significantly lengthened the lifespan of Indianmeal moth.

Adult Reproduction. Long term exposure to 10°C reduced the number of eggs laid per female (Table 1). Moths exposed to 10°C produced significantly fewer eggs than untreated moths, but there was no difference between moths mated before exposure (mated) and those mated after exposure (unmated). The number of eggs laid by moths exposed to 10°C for ≥ 15 days was reduced by over 50% when compared to untreated moths.

The percentage of viable eggs from moths exposed to 10°C was also significantly lower than that from untreated moths. Moths exposed to 10°C before mating produced slightly more viable eggs than did moths that had mated before exposure. Because the difference was so slight, we pooled the values for both treatment groups (mated and unmated) in further analyses. Regression analysis on arcsine transformed data gave the linear equation $y = 73.53 - 2.28x$, with an R^2 value of 0.78. The estimated exposure time needed for a 95% reduction of viable eggs was 27 days. Adult female mortality at a comparable exposure time (28 days) was only 10%.

Egg Mortality. Eggs were relatively sensitive to exposure to 10°C (Table 2). For all ages, 95% mortality was exceeded after just 12 days of exposure. Egg age had a significant effect on response to 10°C: 30 ± 8 h old eggs were significantly more tolerant than the younger or older eggs. The youngest and oldest ages were statistically similar. Further analysis was limited to the most tolerant age. Logit regression analysis performed on 30 ± 8 h old eggs predicted an exposure of 11.6 days to produce 95% mortality (Fig. 2).

Conclusions

In a proposed integrated management program where incoming product is first disinfested and then protected under low temperature storage, clean product is most vulnerable to attack by flying moths as it is transferred to storage or when storage is opened for product removal. While our work shows that more than half of invading moths may survive low temperatures for 7 weeks or longer, females are nearly sterile after only 4 weeks. Because eggs are killed after 2 weeks of exposure to 10°C, and females ready to oviposit are known to lay their eggs within 1-2 weeks under 10°C, this gives a similar period of 3-4 weeks for complete mortality of any offspring. Thus, clean product that has been under storage at 10°C and has been undisturbed for 4 weeks should be relatively free of Indianmeal moth. The efficiency of low temperature storage may also be enhanced by strict sanitation methods and by moving product during the day, when moths are less likely to be flying.

Table 1. Number and viability of eggs laid by Indianmeal moths exposed to 10°C.

Exposure (days)	Total Eggs per Female			Percentage Viable Eggs		
	Untreated	Mated	Unmated	Untreated	Mated	Unmated
5	432.8 a	273.9 b	329.3 ba	90.7 a	74.3 a	85.7 a
10	369.9 a	238.4 a	236.4 a	85.3 a	56.0 a	50.5 a
15	398.7 a	171.4 b	252.5 b	89.3 a	41.3 b	52.3 b
20	451.1 a	146.3 b	187.0 b	92.7 a	12.7 b	28.3 b
25	325.1 a	147.5 b	149.6 b	87.0 a	10.0 b	9.3 b
30	369.8 a	152.8 b	140.4 b	85.3 a	0	5.3 b

Values are means of 4 replicates of 10 moths each. Among treatments for each variable and exposure, means followed by different letters are significantly different ($P \geq 0.05$, Tukey's studentized test). Analysis performed on arcsine transformed values for percentage viable eggs.

Table 2. Percent mortality of different ages of Indianmeal moth eggs exposed to 10°C.

Exposure (days)	Age of Eggs		
	9 ± 8 h old	30 ± 8 h old	54 ± 8 h old
4	34.4	3.2	34.8
6	44.3	7.5	59.9
8	59.4	27.8	86.3
10	87.2	79.0	96.9
12	98.1	96.4	99.3
14	100.0	99.9	99.5
16	100.0	100.0	99.8

Mean values of 4 replicates of about 300 eggs each for 9 and 30 h old eggs, 3 replicates for 54 h old eggs.